Non-isothermal propagation and arrest of km-sized km-deep sills at calderas

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Motivation

The mechanism controlling magmatic sill formation is under investigation since decades, but important questions are still partly unanswered, among which:

- How do sills spread?
- Why can magma propagate for kilometers without solidifying?
- Why do ground deformation data rarely, if ever, detect sill propagation, while they usually evidence inflation?

What follows is our small contribution to give an answer to these questions.

More details in

Amoruso, A., & Crescentini, L. (2019). An approximate approach to nonisothermal emplacement of kilometer-sized kilometer-deep sills at calderas. *Journal of Geophysical Research: Solid Earth*, 124. https://doi.org/10.1029/2018JB016254

Keypoints

1) Km-sized km-deep magmatic sills spread in homogeneous rock or along a rock interface like hydraulic fractures do in an infinite medium.

2) The small lag between the magma and fracture fronts slightly affects spreading velocity but greatly defers stopping by magma solidification.

3) For sill radii shorter than 2-3 km, the ground deformation pattern is about constant during spreading, as for a stationary inflating source.

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1) *Km-sized km-deep magmatic sills spread in homogeneous rock or along a rock interface like hydraulic fractures in an infinite medium.*

If depth-to-radius is larger than 1, the sill inflates as in an infinite medium; thus, elasticity equations are like those used for hydraulic fracturing.

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The physics of the process is described by the same equations both in the case of magmatic sills and hydraulic fractures, because a viscous fluid is always involved.

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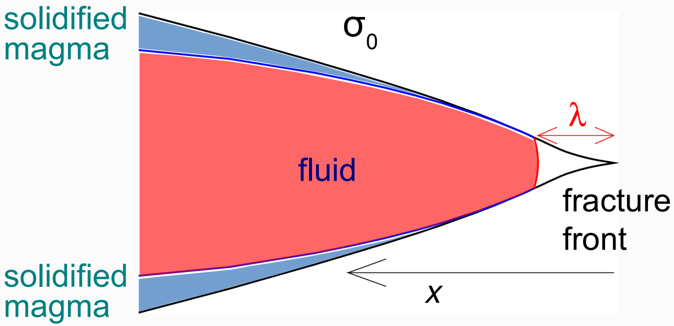
We take advantage of previous studies on hydraulic fracturing (for a review, e. g. Detournay, Annu. Rev. Fluid Mech., 2016)

2) The small lag between the magma and fracture fronts slightly affects spreading velocity but greatly defers stopping by magma solidification.

A lag λ, filled with vapors exsolved from the fluid and/or the rock, must exists between the fluid and fracture fronts (e. g. Garagash and Detournay, 2000 as for isothermal propagation).



We find that:

Heat exchange between magma and the hosting rock is effective only behind the lag, as thermal conductivity of the lag filling vapors is much smaller than that of the rock.

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The maximum achievable sill radius is much larger (orders of magnitude) than if the lag were absent.

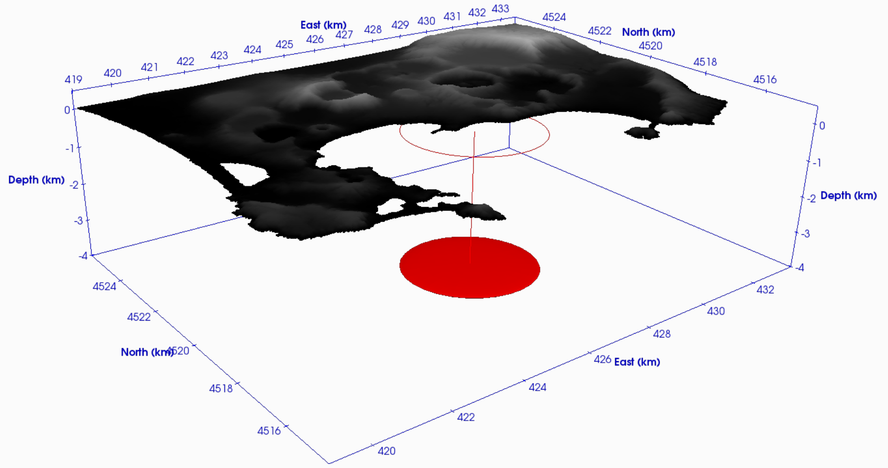
3) For sill radii shorter than 2-3 km, the ground deformation pattern is about constant during spreading, as for a stationary inflating source.

Ground deformation data can capture the sill propagation phase only if the ground deformation pattern evolves appreciably over time.

In the case of Campi Flegrei caldera (Italy), sill radius R is about 2000 m and depth is about 3500 m:

- ground displacements for R ≤ 1000 m are very small
- ground deformation pattern is almost constant up to R ≈ 3000 m

thus ground deformation seems generated by a stationary inflating source.



Thanks for your attention

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